

CLAIMS

~~What is claimed is:~~

1. A substrate processing system comprising:

N processing chambers ~~one or more processing chambers~~ defining N reaction volumes, wherein N is an integer greater than one;

N-1 first valves arranged between the N reaction volumes, wherein a reaction volume refers to a volume in which a substrate is exposed to a precursor gas; and

a controller in communication with the N-1 first valves and configured to:
 pressurize a first one of the N reaction volumes with the precursor gas to a first target pressure;

wait a first predetermined soak period;

evacuate a second one of the N reaction volumes to a second target pressure that is lower than the first target pressure;

open one of the N-1 first valves between the first one of the N reaction volumes and a~~the~~ second one of the N reaction volumes;

close the one of the N-1 first valves subsequent to the opening of the one of the N-1 first valves; and

introduce an additional amount of the precursor gas to the second one of the N reaction volumes to achieve a third target pressure after the closing of the one of the N-1 first valves; and

N-1 compressors and N-1 second valves arranged between the N reaction volumes,

wherein:

the controller is further in communication with the N-1 compressors and the N-1 second valves; and

the controller is configured to:

after evacuating the second one of the N reaction volumes to the second target pressure, open one of the N-1 second valves between the first one of the N reaction volumes and the second one of the N reaction volumes; and
operate one of the N-1 compressors to drive the precursor gas from the first one of the N reaction volumes via one of the N-1 first valves to the second one of the N reaction volumes via one of the N-1 second valves.

2. The substrate processing system of claim 1, further comprising N pressure sensors that measure pressure in the N reaction volumes, respectively, wherein the controller is configured to communicate with the N pressure sensors.

3. The substrate processing system of claim 1, further comprising N pumps in fluid communication with the N reaction volumes via N second valves, wherein the controller is configured to selectively operate the N pumps and the N second valves.

4. The substrate processing system of claim 1, wherein the controller is configured to:

wait until a predetermined pressure relationship exists between the first one of the N reaction volumes and the second one of the N reaction volumes; and

perform the closing of the one of the N-1 first valves in response to the predetermined pressure relationship existing between the first one of the N reaction volumes and the second one of the N reaction volumes.

5. The substrate processing system of claim 4, wherein the predetermined pressure relationship is pressure equilibrium.

6. The substrate processing system of claim 4, wherein the controller is configured to purge a residual precursor gas from the first one of the N reaction volumes.

7. The substrate processing system of claim 1, wherein the controller is configured to:

wait a second predetermined soak period; and

cascade the precursor gas in the second one of the N reaction volumes to an additional one of the N reaction volumes.

~~8. The substrate processing system of claim 1, further comprising N-1 compressors and N-1 second valves arranged between the N reaction volumes, wherein:~~

~~the controller is further in communication with the N-1 compressors and the N-1 second valves; and~~

~~the controller is configured to:~~

~~after evacuating the second one of the N reaction volumes to the second target pressure, open one of the N-1 second valves between the first one of the N reaction volumes and the second one of the N reaction volumes; and~~

~~operate one of the N-1 compressors to drive the precursor gas from the first one of the N reaction volumes to the second one of the N reaction volumes.~~

~~9.8.~~ The substrate processing system of ~~claim 8~~claim 1, wherein the controller is configured to close the one of the N-1 first valves and the one of the N-1 second valves.

~~10.9.~~The substrate processing system of claim ~~98~~, wherein the controller is configured to add an additional amount of the precursor gas to the second one of the N reaction volumes to achieve ~~a~~the third target pressure.

~~11-10~~. The substrate processing system of claim ~~98~~, wherein the controller is configured to purge a residual precursor from the first one of the N reaction volumes.

~~12-11~~. A substrate processing system comprising:

a processing chamber defining a reaction volume;

a first valve arranged between the reaction volume and a storage volume, wherein the storage volume is void of a reaction volume, and wherein a reaction volume refers to a volume in which a substrate is exposed to a precursor gas;

a controller in communication with the first valve and configured to:

pressurize the reaction volume with the precursor gas to a first target pressure;

wait a predetermined soak period;

evacuate the storage volume to a pressure that is lower than the first target pressure; and

open the first valve;

a second valve arranged between the first valve and the storage volume; and

a compressor arranged between the first valve and the second valve,

wherein the controller communicates with the second valve and the compressor and is ~~configured to operate the first valve, the second valve and the compressor to drive the precursor gas from the reaction volume to the storage volume~~configured to: subsequent to opening the first valve, operate the first valve, the second valve and the compressor to drive the precursor gas from the reaction volume of the processing chamber to the storage volume, and subsequent to driving the precursor gas from the reaction volume of the processing chamber to the storage volume, pump the precursor gas back from the storage volume through the compressor to the reaction volume.

~~13-12~~. The substrate processing system of claim ~~12-11~~, further comprising:

a pressure sensor that measures pressure in the reaction volume of the processing chamber; and

a pump in fluid communication with the reaction volume via a third valve, wherein the controller communicates with the pressure sensor, the pump and the third valve.

~~14~~13. The substrate processing system of claim ~~12~~11, wherein the controller is configured to close the first valve and the second valve.

~~15~~14. The substrate processing system of claim ~~12~~11, wherein the controller is configured to purge a residual precursor ~~from the reaction volume~~ gas from the reaction volume of the processing chamber.

~~16~~15. The substrate processing system of claim ~~15~~14, wherein the controller is configured to:

open the first valve and the second valve between the reaction volume and the storage volume; and

operate the compressor to drive the precursor gas from the storage volume to the reaction volume.

~~17~~16. The substrate processing system of claim ~~12~~11, further comprising:

N additional reaction volumes;

N additional valves connecting the N additional reaction volumes to the compressor,

wherein the controller is configured to:

open one of the first valve or one of the N additional valves;

open the second valve; and

operate the compressor to pump the precursor gas from the storage volume to one of the reaction volume or one of the N additional reaction volumes.

~~18~~17. A method comprising:

pressurizing a first one of N reaction volumes with a precursor gas to a first target pressure, wherein a reaction volume refers to a volume in which a substrate is exposed to a precursor gas;

waiting a first predetermined soak period;

evacuating a second one of the N reaction volumes to a second target pressure that is lower than the first target pressure;

opening one of N-1 first valves between the first one of the N reaction volumes and ~~at the~~ the second one of the N reaction volumes;

after evacuating the second one of the N reaction volumes to the second target, opening one of N-1 second valves between the first one of the N reaction volumes and the second one of the N reaction volumes; and

operating one of N-1 compressors between the N reaction volumes to drive the precursor gas from the first one of the N reaction volumes ~~to the second one of the N reaction volumes~~ via one of the N-1 first valves to the second one of the N reaction volumes via one of the N-1 second valves.

~~19~~18. The method of claim ~~18~~17, further comprising:

waiting until a predetermined pressure relationship occurs between the first one of the N reaction volumes and the second one of the N reaction volumes; and

closing the first one of the N-1 first valves.

~~20~~19. The method of claim ~~19~~18, wherein the predetermined pressure relationship is pressure equilibrium.

~~21~~20. The method of claim ~~19~~18, further comprising introducing an additional amount of the precursor gas to the second one of the N reaction volumes to achieve a third target pressure after closing the first one of the N-1 first valves.

~~22-21.~~ The method of claim ~~1918~~, further comprising purging_a residual precursor gas from the first reaction volume.

~~23-22.~~ The method of claim ~~2120~~, further comprising:
 waiting a second predetermined soak period; and
 cascading the precursor gas to an additional one of the N reaction volumes.

~~24-23.~~ The method of claim ~~1817~~, further comprising closing the one of the N-1 first valves and the one of the N-1 second valves.

~~25-24.~~ The method of claim ~~2423~~, further comprising adding an additional amount of the precursor gas to the second one of the N reaction volumes to achieve a third target pressure.

~~26-25.~~ The method of claim ~~2423~~, further comprising purging_a residual precursor gas from the first one of the N reaction volumes.

~~27-26.~~ A method of operating a substrate processing system comprising:
 pressurizing a reaction volume ~~with precursor gas to a first target pressure~~
in a processing chamber with a precursor gas to a first target pressure;
 waiting a predetermined soak period;
 evacuating a storage volume to a pressure that is lower than the first target pressure, wherein the storage volume is void of a reaction volume, and wherein a reaction volume refers to a volume in which a substrate is exposed to the precursor gas;
 opening a first valve located between the reaction volume of the processing chamber and the storage volume;
 opening a second valve between the first valve and the storage volume;
 and

operating a compressor between the first valve and the storage volume ~~to drive the precursor gas from the reaction volume to the storage volume~~ to: drive the precursor gas from the reaction volume of the processing chamber to the storage volume, and subsequent to driving the precursor gas from the reaction volume of the processing chamber to the storage volume, pump the precursor gas back from the storage volume through the compressor to the reaction volume.

~~28.~~27. The method of claim ~~27~~26, further comprising closing the first valve and the second valve.

~~29.~~28. The method of claim ~~27~~26, further comprising purging a residual precursor gas from the reaction volume of the processing chamber.

~~30.~~29. The method of claim ~~27~~26, further comprising:

opening the first valve and the second valve between the reaction volume of the processing chamber and the storage volume; and

operating the compressor to drive the precursor gas from the storage volume to the reaction volume of the processing chamber.

~~31.~~30. The method of claim ~~27~~26, further comprising:

opening the first valve or one of N additional valves, wherein the N additional valves connect N additional reaction volumes to the compressor;

opening the second valve; and

operating the compressor to pump the precursor gas from the storage volume ~~to one of~~ the reaction volume of the processing chamber or one of the N additional reaction volumes.